Characteristics of Allegheny Woodrat (*Neotoma magister*) Habitat in the New River Gorge National River, West Virginia

Final Project Report

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Introduction

The Allegheny woodrat (*Neotoma magister*) is closely tied to rock outcrops, cliff and talus slopes, and caves within the Central and Southern Appalachians from New York to Tennessee (Wiley 1980, Hall 1981). It is listed as threatened, endangered, or as a species of special concern in Indiana, Maryland, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Virginia, and West Virginia due to population declines. Prior to the moratorium placed on the endangered species listing process under federal guidelines, this species was designated as a candidate Category II animal in response to apparent population declines in states along the

periphery of its range (Balcom and Yahner 1996). Populations in West Virginia are at the core of the distributional range and appear to be stable, although actual population status is unknown (Mengak 1996, Stihler and Wallace 1996).

Management strategies for Allegheny woodrats have been and are being formulated based on information collected in areas removed from this core distributional range. Management implications drawn from states on the periphery of the range may not be applicable to states where populations are more stable. Further, forest fragmentation associated with forest management practices may be contributing to population declines. Edge habitats may create favorable conditions for mammalian predators, such as raccoons, which could act as direct predators and/or pathogen vectors. With increased timber harvesting on private lands in the mid-Atlantic, public lands where timber harvesting does not occur may become increasingly important for maintaining stable populations of woodrats.

The New River Gorge National River (NRGNR) contains considerable rocky habitat along the New, Gauley, and Meadow Rivers. These areas are known to contain woodrat populations, but the size and extent of these populations are not known. Further, characteristics of habitat used by woodrats in NRGNR have not been identified. In this project, we developed baseline information on woodrat population size, extent, and habitat characteristics in the NRGNR.

Contributions to a Statewide Study

Because of the dispersed distribution of rocky habitats in the landscape, Allegheny woodrats may exhibit a metapopulation structure. A metapopulation is defined as a population comprised of smaller populations that experience periodic extinction and subsequent recolonization (Levins 1969). According to metapopulation theory, there must be potential for dispersal within the metapopulation to recolonize extirpated populations and maintain overall

genetic diversity. Within NRGNR, rivers and highways may act as barriers to dispersal and consequently to gene flow. We conducted a study examining gene flow among woodrat populations throughout West Virginia and adjacent states using microsatellite DNA analyses (see Castleberry 2000 for details). A small tissue sample was collected from each woodrat trapped on NRGNR and was included in DNA analyses for this larger study. Gene flow estimates were low among subpopulations suggesting that dispersal is limited, even among subpopulations separated by less than 3 km (Castleberry 2000). In some cases, individual colonies had significant genetic differentiation from nearby populations. Consequently, individual colonies or aggregations of geographically proximate colonies should be recognized as management units and management strategies should emphasize retention of dispersal corridors to maintain gene flow (Castleberry 2000). At NRGNR, the New River did not act as a barrier to gene flow, although subpopulations on the same side of the river were more similar to each other than to those across the river.

Methods

Field methods

Throughout NRGNR, rocky habitats were searched for evidence and condition of woodrat sign, such as latrine areas or middens. Sites with evidence of woodrats as well as sites with no evidence of woodrats but that exhibited suitable rock size and structure were trapped. Because woodrats are known to use abandoned mines, we placed some of the trapping stations at the openings of abandoned, deep mine portals and at mine portals that had been closed. All trapping sites were selected with input from the NRGNR resource management staff.

Traps were placed systematically at the base of cliffs and large rocks near the cliff face (float blocks), within boulder fields, and at the openings of mine portals. When nests and

latrine sites were present, traps were placed near them. We trapped each site for 2 consecutive nights using up to 40 Tomahawk live traps baited with an apple. The number of traps used at a site depended on site size. I had originally proposed to trap at each site 2 different times over the course of the summer if time allowed. However, because we found such a large number of potentially suitable sites, each site was trapped only once to allow sampling at a greater number of different sites.

Upon capture, age, sex, weight, and reproductive condition were recorded and each animal was marked with a Monel #1 ear-tag in each ear to provide long-term information upon subsequent recaptures. Age class was based on body mass ($\leq$175 g = juvenile; 176-225 g = subadult; >225 g = adult) and pelage coloration (Mengak person. commun.). Each animal was weighed to the nearest gram using a 500-g Pesola scale. A site was considered occupied if at least one individual was captured.

All sites trapped were plotted on USGS 7.5 minute topographic maps (Appendix 1). The location of each captured animal was mapped on the same topographic maps. Universal Transverse Mercator (UTM) coordinates were determined for each capture point from the topographic maps.

Vegetation structure and composition was measured on at least one 0.04 ha circular plot at each occupied site using methods similar to those outlined by James and Shugart (1970) and Myers (1997). Characteristics measured included stem densities of shrubs, saplings, poles, and trees by species; 11 categories of ground cover (forbs, grass, fern, shrub, greenbrier, blackberry, leaf litter, woody debris, rock, bare ground, water); percent canopy cover, slope, and aspect (Appendix 2). The plot was placed at the location of a woodrat capture. When woodrats were captured at more than one location and vegetation characteristics appeared to differ markedly among the capture locations, additional vegetation

plots were sampled to account for site variability. When a site had more than one vegetation plot, means were calculated for each vegetation variable.

Physical characteristics of the rocky habitats trapped were characterized at each vegetation plot following modified methods from the Pennsylvania Bureau of Wildlife Management's Allegheny Woodrat Site Survey protocol (Pennsylvania Game Commission 1996) and Myers (1997). Attributes recorded at each site were aspect, slope, elevation, site length, site width, rocky habitat type, type of and distance to nearest habitat disturbance, and forest cover type (Appendix 2). Rocky habitat was characterized by placing each outcrop trapped into 1 of 24 rock classifications based on habitat type, quality of habitat, and size of rocks (Pennsylvania Game Commission 1996). Blank data sheets, detailed methods, and coding sheets for physical and vegetative characteristics are in Appendix 2.

Analysis methods

Because trapping effort varied by site (i.e. number of traps set did not always equal 40), the total number of individuals captured was converted to adjusted abundance, a standardized measure of number of individuals captured per 100 trap nights. A trap night is calculated as the total number of traps set, multiplied by the number of nights traps are open, minus ½ of the number of traps sprung (Nelson and Clark 1972). A trap night also takes into account sprung traps because they are not available to capture a woodrat. Adjusted abundance is the number of individual woodrats captured, divided by the number of trap nights, multiplied by 100.

I had proposed to statistically test physical and vegetative characteristics to determine if differences exist between occupied and unoccupied sites. However, only 2 sites had no woodrat captures (Carnifex Ferry 2 and Endless Wall 1; Table 1) and were classed as unoccupied. Therefore, sample sizes were too small for statistical comparisons of physical and vegetative characteristics between occupied and unoccupied sites. Instead, I compared adjusted abundance of woodrats at each site to physical and vegetative characteristics with

multiple regression to determine if any of these characteristics were significantly related to woodrat abundance. Variables entered into the regression models at á $\leq$ 0.15. Statistical significance was set at á=0.05.

Variables initially considered in the multiple regression models were percent canopy cover, stem densities of shrubs, saplings (<3 cm dbh), poles (3-8 cm dbh), and 4 categories of trees (>8 cm dbh), 2 measures of species richness (shrubs/saplings/poles combined and trees), 4 categories of percent ground cover (shrub; green=forb+grass+fern+moss; non-vegetative=rock+woody debris; briars=greenbriar+blackberry), disturbance level, and rocky habitat type. The 4 categories of trees were hard mast producing tree species, soft mast producing species, species of trees that produce other types of seeds woodrats are known to consume (eg. maple, ash, pine), and species of trees that woodrats could consume their leaves. The disturbance level variable was the product of proximity of the disturbance (1=on site; 2=off-site but within 100 m; 3=>100 m off-site) and the type of disturbance (1=high recreational use; 2=moderate recreational use; 3=low recreational use; 4=paved road; 5=gravel road).

Results and Discussion

Capture success

From 25 May to 12 August 1999, 22 sites were trapped for woodrats with 0-7 different individuals captured at a given site (Table 1). The majority of sites had low capture rates. Two sites had no woodrat captures, while 6 had 1 individual captured. Based on both adjusted abundance and number of individuals captured, the most productive sites for woodrat captures were Underwood on the Meadow River and Ames Mines, Butcher's Branch, Beauty Mountain, Kaymoor Mines, and Tunnel Trails on the New River with 4-7 different individuals captured at

each site. These sites should be considered for potential long-term monitoring sites. Access to all of these sites is relatively easy with the exception of Beauty Mountain.

Over all sites at NRGNR, 20% of the 60 individuals captured were juveniles, while 8.3% were non-breeding subadults (Table 1). This is only slightly lower than the proportion of juveniles and subadults captured in other areas of West Virginia. On 2 study areas in northern WV, 21.1% of 76 individuals were juveniles and 11.8% were subadults (Zuck, Wood, and Edwards, unpubl. data). On the Westvaco Research Forest in central West Virginia, 25.7% of 70 individuals captured were juveniles and 10% were subadults (Castleberry, Wood, and Ford, unpubl. data). One possible reason for this slight difference is that on NRGNR each site was trapped only once, while sites in the other studies were trapped multiple times which increases the probability that most animals at a site will be captured.

Age ratios at NRGNR varied considerably by site with the proportion of juveniles captured ranging from 0-100% of individuals. This variability may be due to variability in habitat quality, e.g. reproductive rates at some sites may be low due to low habitat quality. Four adult females were lactating at the time of capture, one at each of 4 sites (Elverton Mines, Kaymoor Mines, Butcher's Branch, and Beauty Mountain). Excepting Elverton Mines, these sites had relatively high proportions (33-50%) of juveniles captured suggesting they have good habitat quality.

Sex ratios of adult woodrats at NRGNR were skewed towards males. Only 4 of the 22 sites trapped on NRGNR had more females captured than males. Of the 43 different adults captured, 65.1% were male and 34.9% female (Table 1). In northern West Virginia, the adult sex ratio was almost equal at 51% female and 49% male (n=51 adults; Zuck, Wood, and Edwards, unpubl. data). In a study in Kentucky, 53% of captures were males (unpubl. data from Steven Thomas, Wildlife Biologist, Kentucky Dept. of Fish and Wildlife Resources). The differences in sex ratios in these studies may have resulted from differences in trapping intensity. Sites in northern WV and Kentucky were trapped several times each year whereas

each site at NRGNR was trapped only once. When females have dependent young, they are less prone to capture because they spend more time at the den site nursing young. Males are known to wander more widely and are not tied to a den site and thus are more prone to capture. Consequently, females are more likely to be missed when a site is trapped only once.

Habitat characteristics and disturbance

Adjusted abundance of woodrats was related to physical and vegetative characteristics (Table 2) with multiple regression analyses. Four variables (Table 3) explained 65% of the variation in adjusted abundance of all woodrats: disturbance level, green ground cover, shrub cover, and stem density of pole-size trees. Consequently, 35% of the variation in woodrat abundance was not explained by the variables that we examined. Disturbance level (Figure 1) had a positive relationship and amount of green ground cover (Figure 2) showed a negative relationship with woodrat abundance at $P \leq 0.05$. Woodrat abundance was low where amount of green ground cover was high.

Adjusted abundance of juveniles also was related to physical and vegetative characteristics with multiple regression analyses. Three variables accounted for only 31% of the variability in juvenile abundance (Table 3); therefore considerable variability was not explained by this model. Juvenile abundance was positively related to disturbance levels at $P=0.03$.

The single best predictor of overall woodrat abundance was disturbance levels, with a partial R^2 of 0.35 (Table 3). This indicates that disturbance levels explained 35% of the variability; greatest abundance occurred where disturbance was highest (Figure 1). This is opposite of what I expected; i.e. that woodrat abundance would be lower where human disturbance near rocky habitats was high. One site (Endless Wall 1) is a popular climbing spot and had very high levels of human disturbance. However, this was the only site with high human disturbance that had no woodrat captures (Table 4). Nine of the 22 sites trapped were

classed as having very high or high levels of human disturbance. It is possible that high human use generally equated with higher food resources for woodrats due to discarded food remains by people using an area. However, this study was not designed to look specifically at disturbance levels. This result warrants further investigation with a study designed to look specifically at sites with varying levels of disturbance and that has greater sampling intensity over multiple years. In addition, habitat surrounding these sites should be examined to determine if landscape context affects woodrat use of highly disturbed areas. For example, if woodrats use a site with high human disturbance levels, does the surrounding habitat need to be undisturbed?

Effects of mine portals

Six of the sites trapped included mine portals (Table 5). We captured no woodrats at mine portals that had been completely closed by backfilling even when mitigation pipes were present. Further, there was no evidence that woodrats were using mitigation pipes at any sites. At the Elverton Mine site, all portals had been backfilled and mitigated with an 8-inch plastic pipe the previous summer. During 1998 before portals were backfilled, woodrats were captured at portal openings by WVDNR personnel. We captured no woodrats at these closed portals in 1999. The one woodrat captured at the Elverton Mines site was in a large boulder field away from the closed portals. A woodrat was captured at the Nuttall Cliffs site at a mine portal that had been backfilled but had developed a small opening with air flow through the opening. Although this portal was fitted with a mitigation pipe, the pipe had not been used by woodrats; it was obviously unused because it was clogged with leaves and nearly buried in litter. Generally, woodrats were captured at all open, gated, or backfilled mine portals where an opening had redeveloped.

Conclusions and Recommendations

The objective of this study was to obtain baseline information on woodrat population size, extent, and habitat characteristics in the NRGNR. We determined that woodrats occurred at 90% (20 of 22) sites trapped along the Gauley, Meadow, and New Rivers, although at the majority of sites they were captured in low numbers. Large amounts of potentially suitable habitat were not sampled, but it is likely that many of these sites support woodrats.

Few habitat characteristics that we measured related to woodrat abundance. The most variability was explained by human disturbance levels, although the relationship was the opposite of expected with higher woodrat abundance where human disturbance was greater. I suggest that this relationship be examined in more detail with a study designed to measure human disturbance levels, woodrat activities, and woodrat abundance over multiple seasons. In this baseline study, each site was visited only once, thus the level of disturbance and woodrat abundance reflect only one point in time. Consequently, it is not appropriate to generalize these results to other sites and over the long-term. In addition, landscape context should be quantified at capture sites. It is important to determine if disturbed sites must be surrounded by undisturbed habitat to be used by woodrats.

Woodrats appear to make extensive use of open, gated, or partially closed mine portals. At sites with 8" plastic mitigation pipes, there was no evidence that woodrats used these as passageways into closed portals. I suggest that partial backfilling of portals will be more beneficial to continued use of mines by woodrats.

I recommend that 4-6 of the sites with high abundance of woodrats be established as long-term population monitoring sites, half with high human disturbance levels and half with low to no disturbance. The sites already trapped for 2 summers should be given highest priority. Each site should be trapped 2-3 times each summer using 40 traps per site. In addition, 4-6 sites should be randomly selected from all remaining sites to serve as statistically

random long-term monitoring sites. These sites also should be trapped 2-3 times each summer using 40 traps per site. Monitoring randomly selected sites is important to provide a statistically valid way to assess population changes over time.

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Table 1. Sites trapped and number woodrats captured at New River Gorge National River and Gauley River National Recreation Area, West Virginia, summer 1999.

Site	Date traps set	# trap nights[a]	Adjusted abundance[b]	Number of Individuals[c]				
				Total	AF	AM	Sub	Juv
Gauley River								
Carnifex Ferry 1	08/03/1999	59	1.7	1	1	0	0	0
Carnifex Ferry 2	08/06/1999	58	0.0	0	0	0	0	0
Summersville Dam 1	07/28/1999	59	1.7	1	0	1	0	0
Summersville Dam 2	07/30/1999	57.5	5.2	3	1	1	0	1
Meadow River							0	
Underwood	07/11/1999	67	9.0	6	0	4	1	1
Mt. Lookout	06/10/1999	59	3.4	2	1	0	0	1
New River								
Ames Cliffs	06/14/1999	49	6.1	3	0	3	0	0
Ames Mines	06/08/1999	71	9.9	7	3	3	0	1
Butcher's Branch	07/14/1999	58	8.6	5	1	2	0	2
Beauty Mountain	08/10/1999	55	10.9	6	2	1	1	2
Cunard South	07/22/1999	40	2.5	1	0	1	0	0
Elverton Mines	05/26/1999	27	3.7	1	1	0	0	0
Endless Wall 1	05/25/1999	63	0.0	0	0	0	0	0
Endless Wall 2	05/28/1999	48	2.1	1	0	0	0	1
Keeney's Creek	06/25/1999	74.5	2.7	2	1	1	0	0
Kaymoor Mines	05/28/1999	29.5	13.6	4	1	1	0	2
Nuttal Cliffs	07/07/1999	53.5	3.7	2	0	2	0	0
Nuttallburg Mines	07/08/1999	77	1.3	1	0	1	0	0
Turkey Spur	07/20/1999	56.5	5.3	3	0	1	2	0
Tunnel Trails	07/20/1999	56.5	10.6	6	2	3	0	1
Wolf Creek	07/01/1999	75.5	2.6	2	0	1	1	0
Wolf Creek 2	07/15/1999	76.5	3.9	3	1	2	0	0
Total Captures				**60**	**15**	**28**	**5**	**12**

[a] # trap nights = (# traps X # nights open) minus 1/2 of # of traps sprung.

[b] Adjusted abundance = total number of individuals captured per 100 trap nights.

[c] AF=adult female; AM=adult male; Sub=subadult; Juv=juvenile.

Table 2. Vegetation characteristics measured at woodrat trapping sites on the Gauley, Meadow, and New Rivers, WV, summer 1999.

Site	Species richness		Stem density (#/0.4 ha)							Percent cover					Adjusted abundance[a]	
	<8cm dbh	>8cm dbh	shrub	saplings	poles	Green >8	HM>8	Other>8	SM>8	canopy	shrub	green	rock	briar	total	juveniles
Gauley River																
Carnifex Ferry 1	3.0	4.0	12.0	3.0	1.0	12.0	0.0	1.0	1.0	90.0	30.0	5.0	40.0	5.0	1.69	0.00
Carnifex Ferry 2	.	.	.	.	.	.	.	.	.	.	.	0.0	0.0	0.0	0	0.00
Summersville Dam 1	6.0	7.0	5.0	3.0	2.0	10.0	0.0	7.0	2.0	90.0	25.0	20.0	10.0	0.0	1.69	0.00
Summersville Dam 2	5.3	5.7	4.0	2.0	3.3	2.0	1.7	5.7	1.0	93.3	11.7	26.7	20.0	0.0	5.22	1.74
GR mean	**4.8**	**5.6**	**7.0**	**2.7**	**2.1**	**8.0**	**0.6**	**4.6**	**1.3**	**91.1**	**22.2**	**17.2**	**23.3**	**1.7**		
Meadow River																
Mt. Lookout	2.5	7.0	9.0	1.5	1.0	11.0	0.0	8.0	3.0	87.5	17.5	12.5	27.5	5.0	3.39	1.69
Underwood	5.0	9.0	17.7	4.3	3.0	9.3	5.3	5.3	5.3	93.3	38.3	6.7	21.7	0.0	8.96	1.49
MR mean	**3.8**	**8.0**	**13.3**	**2.9**	**2.0**	**10.2**	**2.7**	**6.7**	**4.2**	**90.4**	**27.9**	**9.6**	**24.6**	**2.5**		
New River																
Ames Cliffs	5.0	7.0	13.0	1.5	1.0	4.5	3.0	9.0	0.5	87.5	10.0	15.0	27.5	0.0	6.12	0.00
Ames Mines	5.7	8.7	7.0	8.7	3.3	2.0	3.7	11.3	4.0	83.3	21.7	33.3	11.7	0.0	9.86	1.41
Butcher's Branch	3.0	3.3	5.3	2.0	0.7	2.3	0.0	3.7	4.0	35.0	20.0	58.3	5.0	13.3	8.62	3.45
Beauty Mountain	6.0	5.7	6.7	5.0	3.7	6.0	2.7	0.3	2.7	78.3	11.7	15.0	28.3	1.7	10.91	3.64
Cunard South	6.0	5.0	6.0	6.0	1.0	2.0	0.0	11.0	5.0	80.0	10.0	50.0	20.0	0.0	2.5	0.00
Elverton Mines	7.0	7.0	8.0	7.0	5.0	3.0	0.0	12.0	2.0	60.0	10.0	35.0	20.0	0.0	3.7	0.00
Endless Wall 1	.	.	.	.	.	.	.	.	.	.	.	0.0	0.0	0.0	0	0.00
Endless Wall 2	5.0	5.0	4.0	3.0	1.0	18.0	2.0	0.0	1.0	80.0	10.0	60.0	15.0	0.0	2.08	2.08
Keeney's Creek	11.0	6.0	11.0	9.0	7.0	0.0	13.0	2.0	0.0	95.0	5.0	20.0	5.0	5.0	2.68	0.00
Kaymoor Mines	4.0	5.0	13.7	0.7	0.3	9.3	0.7	7.7	1.7	81.7	5.0	23.3	25.0	0.0	13.56	6.78
Nuttal Cliffs	8.0	6.5	11.0	12.0	12.5	2.5	3.0	7.0	2.0	92.5	5.0	40.0	10.0	2.5	3.74	0.00
Nuttallburg Mines	4.0	5.0	3.0	2.0	1.0	5.0	0.0	11.0	3.0	80.0	10.0	65.0	0.0	0.0	1.3	0.00
Turkey Spur	5.0	5.7	19.0	5.7	0.3	1.0	3.0	2.3	5.3	71.7	35.0	18.3	18.3	0.0	5.31	0.00
Tunnel Trails	4.0	5.7	10.7	1.3	1.0	3.0	3.0	5.3	2.0	91.7	11.7	15.0	15.0	8.3	10.62	1.77
Wolf Creek	3.0	4.0	17.0	1.0	8.0	18.0	1.0	3.0	0.0	80.0	15.0	10.0	35.0	0.0	2.65	0.00
Wolf Creek 2	3.0	5.0	8.0	1.0	0.0	7.0	0.0	2.0	0.0	57.5	12.5	47.5	27.5	0.0	3.92	0.00
NR mean	**5.3**	**5.6**	**9.6**	**4.4**	**3.1**	**5.6**	**2.3**	**5.8**	**2.2**	**76.9**	**12.8**	**33.7**	**17.6**	**2.1**		
Overall mean	**5.1**	**5.9**	**9.6**	**4.0**	**2.8**	**6.4**	**2.1**	**5.7**	**2.3**	**80.4**	**15.8**	**28.8**	**19.1**	**2.0**		

[a] Adjusted abundance = total number of individuals captured per 100 trap nights

Table 3. Physical and vegetative characteristics of woodrat trapping sites on the Gauley, Meadow, and New Rivers, WV, during summer 1999 that were significantly related to adjusted abundance of woodrats (multiple regression).

Variable	**Partial R^2**	***t***	***P***
Total adjusted abundance			
disturbance level[a]	0.35	-4.74	0.0003
green ground cover[b]	0.14	-3.37	0.004
shrub cover[b]	0.07	-2.28	0.04
pole stem density[b]	0.09	-1.91	0.08
model $R^2 = 0.65$			
model F = 6.91; *P* = 0.002			
Juvenile adjusted abundance			
disturbance[a]	0.15	-2.33	0.03
sapling stem density[b]	0.17	-2.02	0.06
model $R^2 = 0.31$			
model F = 3.88; *P* = 0.04			

[a] Positive relationship; woodrat abundance was greater where disturbance was higher.

[b] Negative relationship; woodrat abundance decreased when cover and density increased.

Table 4. Human disturbance at sites trapped for woodrats during summer 1999 at New River Gorge National River, WV.

Site	Total # indivs	Indivs / 100 trap nights[a]	Disturbance proximity[b]	Disturbance type[c]	Disturbance score	Descriptions of disturbance
Gauley River						
Carnifex Ferry 1	1	1.7	3	3	9	lightly used hiking trail
Carnifex Ferry 2	0	0.0	2	3	6	lightly used hiking trail
Summersville Dam 1	1	1.7	2	4	8	improved road
Summersville Dam 2	3	5.2	2	4	8	improved road
Meadow River						
Mt. Lookout	2	3.4	2	5	10	unimproved road
Underwood	6	9.0	1	1	1	heavy climbing use
New River						
Ames Cliffs	3	6.1	3	4	12	improved road
Ames Mines	7	9.9	1	2	2	campfire spot, graffiti
Butcher's Branch	5	8.6	1	1	1	heavy climbing
Beauty Mountain	6	10.9	1	1	1	heavy climbing
Cunard South	1	2.5	1	2	2	heavily used hiking trail
Elverton Mines	1	3.7	1	3	3	lightly used hiking trail
Endless Wall 1	0	0.0	1	1	1	heavy use by climbers
Endless Wall 2	1	2.1	3	3	9	some hiking/climbing
Keeney's Creek	2	2.7	2	4	8	unimproved road
Kaymoor Mines	4	13.6	1	1	1	very heavy use by people
Nuttal Cliffs	2	3.7	1	3	3	light recreational use
Nuttallburg Mines	1	1.3	1	3	3	rarely used hiking trail
Turkey Spur	3	5.3	1	1	1	very heavy human use
Tunnel Trails	6	10.6	1	1	1	very heavy human use
Wolf Creek	2	2.6	3	3	9	light use hiking trail
Wolf Creek 2	3	3.9	2	3	6	light use hiking trail

[a] Adjusted abundance = total number of individuals captured per 100 trap nights
[b] 1=on site; 2=off-site but within 100 m; 3=>100 m off-site
[c] 1=high recreational use; 2=moderate recreational use; 3=low recreational use; 4=paved road; 5=gravel road.

Table 5. Mine portals trapped for woodrats at New River Gorge National River, WV, summer 1999.

Site	# Indivs captured	Adjusted abundance[a]	Condition of portals trapped
Ames Mines	7	9.9	mine portal open
			mine portal partially closed; campfire, graffiti
Cunard South	1	2.5	mine portal backfilled, but some openings have developed and have airflow
Elverton Mines	1	3.7	portals filled, mitigated w/ drainage pipes (no woodrats captured at portals)
Kaymoor Mines	4	13.6	gated mine
Nuttal Cliffs	2	3.7	portal backfilled, but small opening has developed and has airflow
Nuttallburg Mines	1	1.3	gated mine
			backfilled portal, but now partially open

[a] Adjusted abundance = total number of individuals captured per 100 trap nights

Figure 1. Relationship of woodrat abundance (mean number of woodrats trapped per 100 trap nights) to levels of human disturbance at New River Gorge National River, WV, summer 1999.

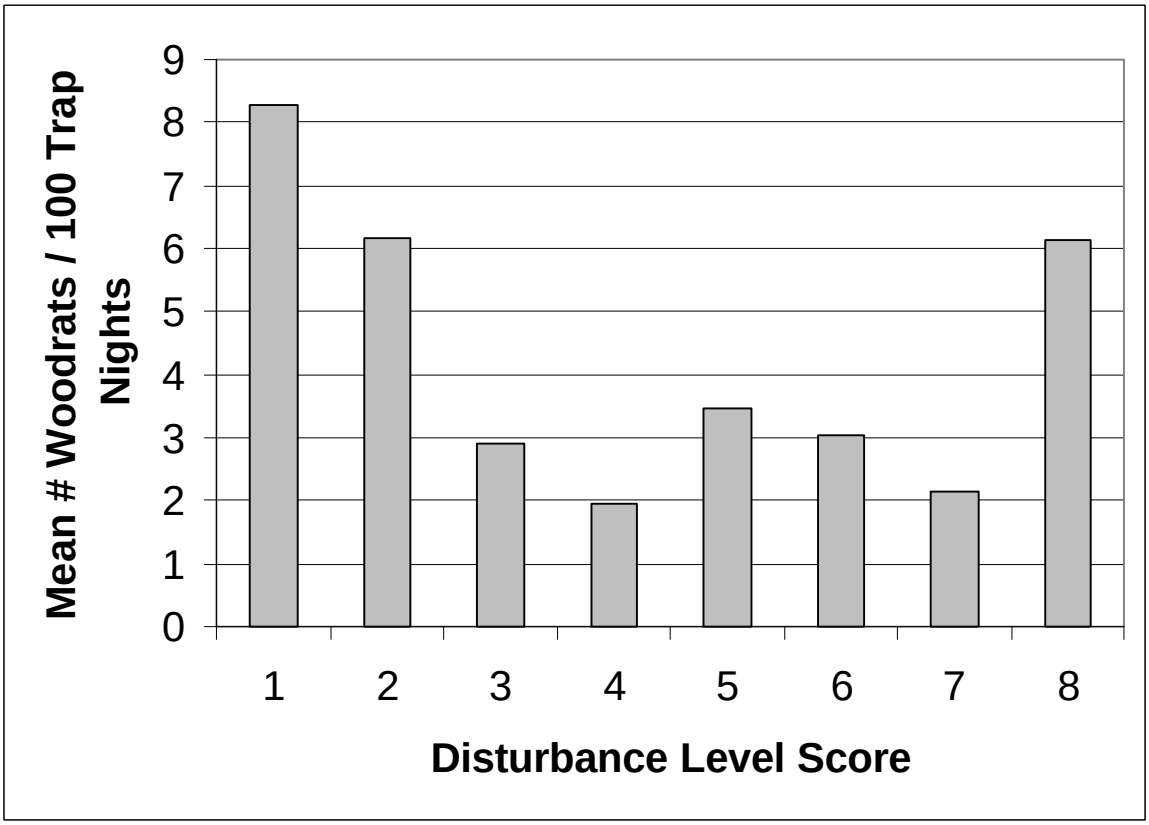
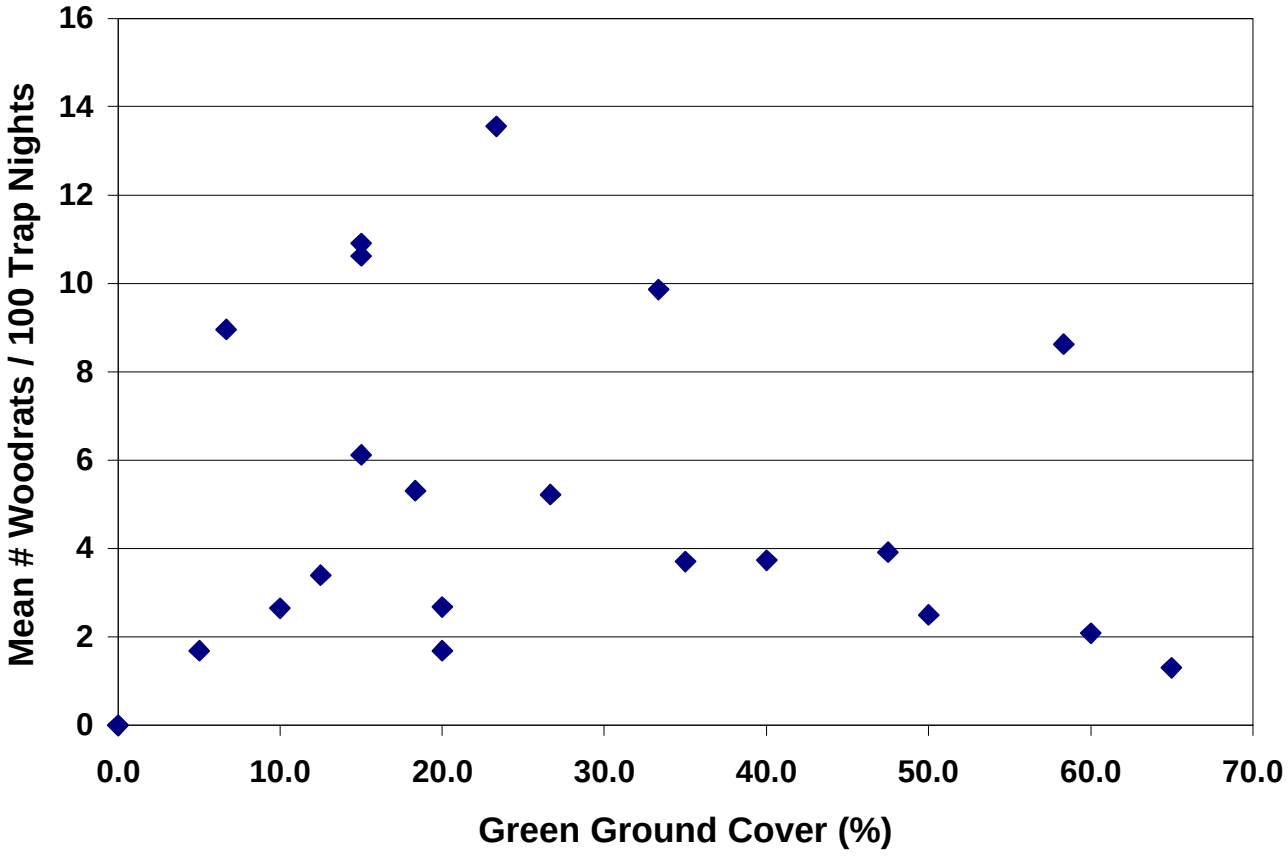


Figure 2. Relationship of woodrat abundance (mean number of woodrats trapped per 100 trap nights) and amount of green ground cover at New River Gorge National River, WV, summer 1999.



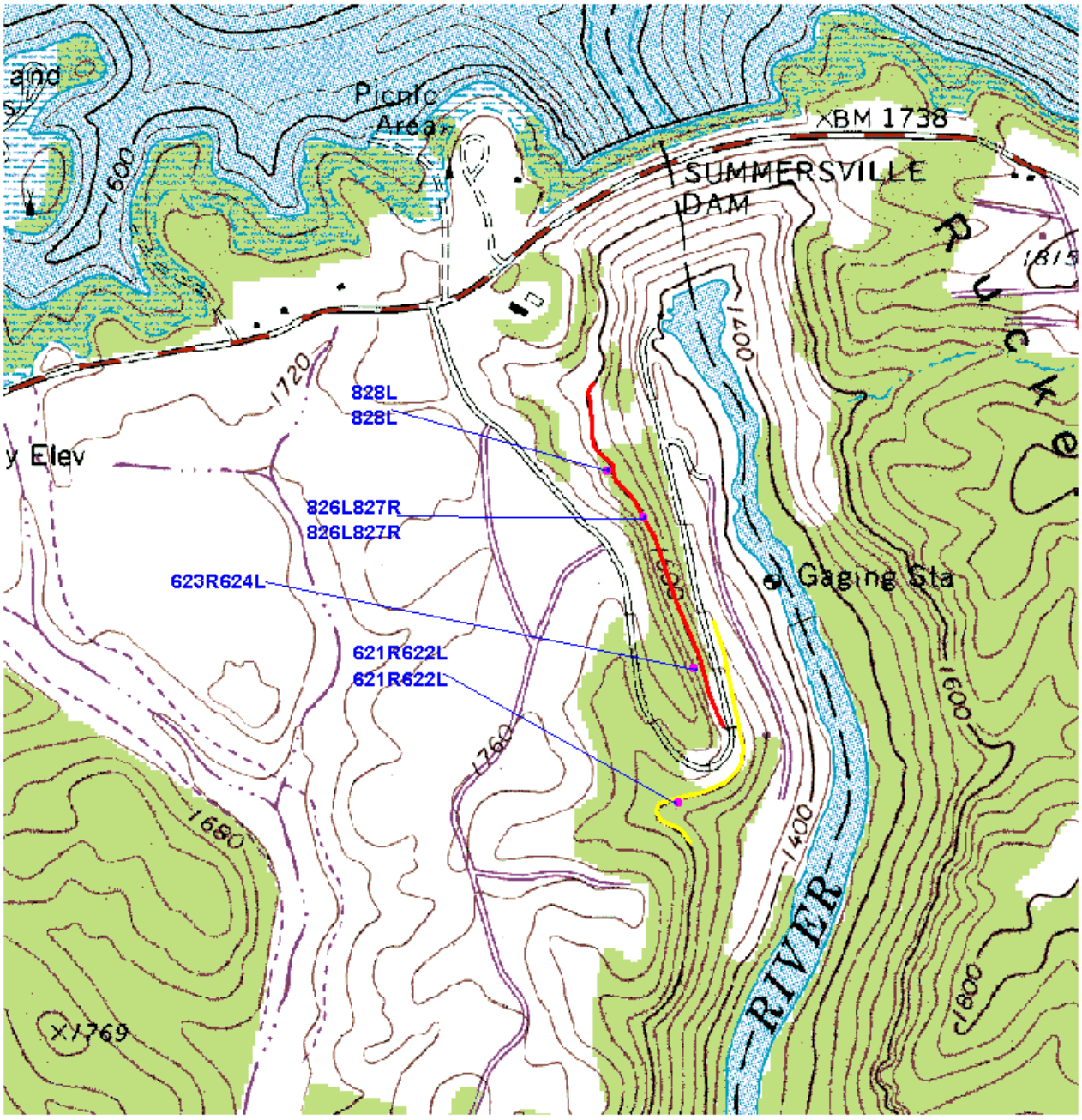
Appendix 1. Site locations and capture points plotted on topographic maps for the following quads and sites. When sites are listed together, they occur on the same map page. Map pages occur in the appendix in the order listed.

Summersville Dam Quad
- Summersville Dam #2, Summersville Dam #1
- Canifex Ferry #1, Carnifex Ferry #2
- Mt Lookout
- Underwood Road

Fayetteville Quad -
- Ames Mines, Ames Cliff
- Wolf Creek #2, Wolf Creek #1
- Endless Wall #2, Endless Wall #1
- Kaymoor Mines
- Butcher's Branch
- Nuttallberg Mines, Nuttall Cliff
- Beauty Mountain
- Elverton Mines
- Keeney's Creek

Fayetteville/Thurmond Quads
- Cunard South

Prince Quad
- Turkey Spur
- Tunnel Trail



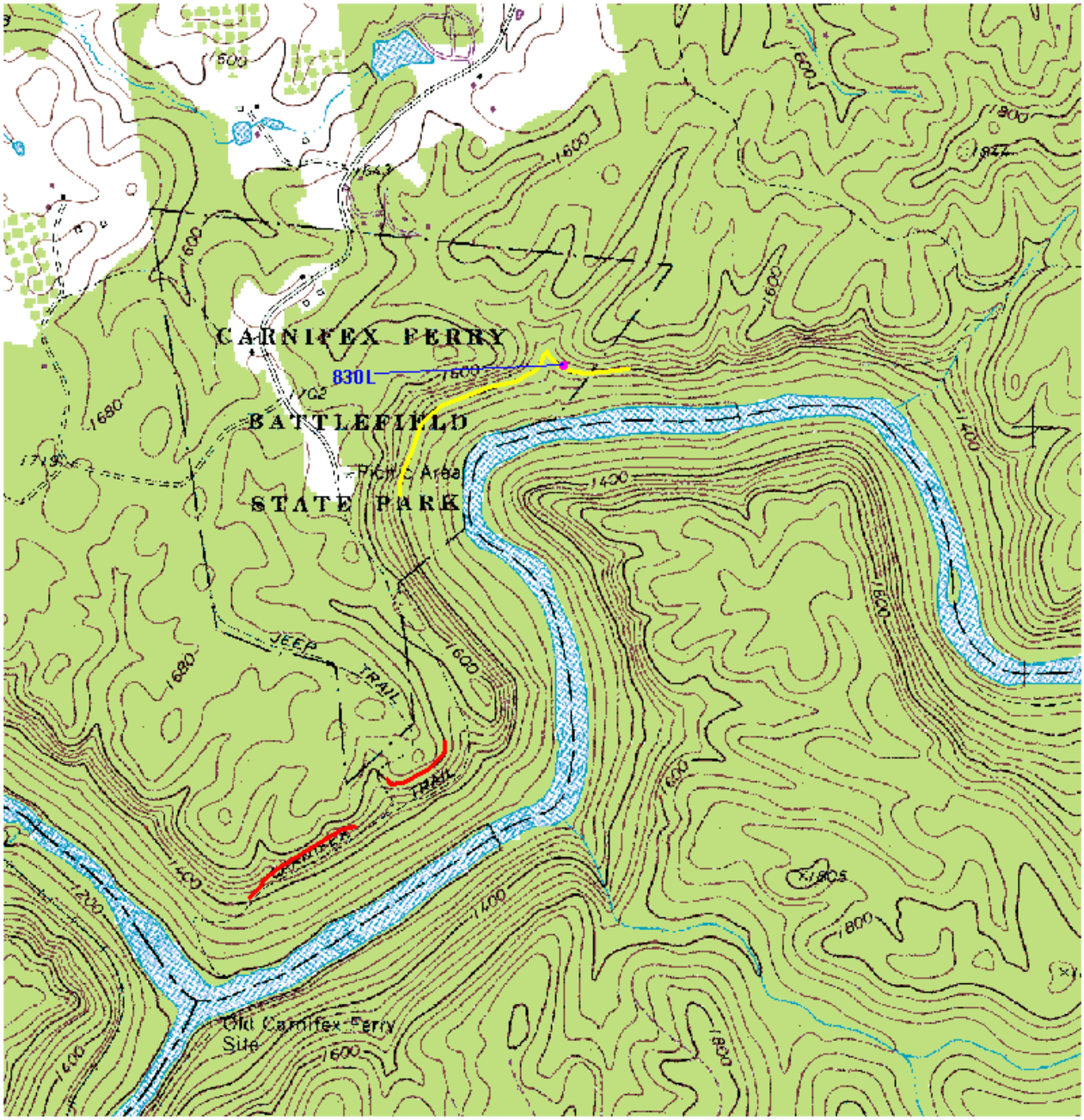
Individual Captures
Summersville Dam #1
Summersville Dam #2

100 0 100 200 Meters

N
W E
S

(Summer 1999)

(Summersville Dam Quad -
Summersville Dam # 1, Summersville Dam # 2)



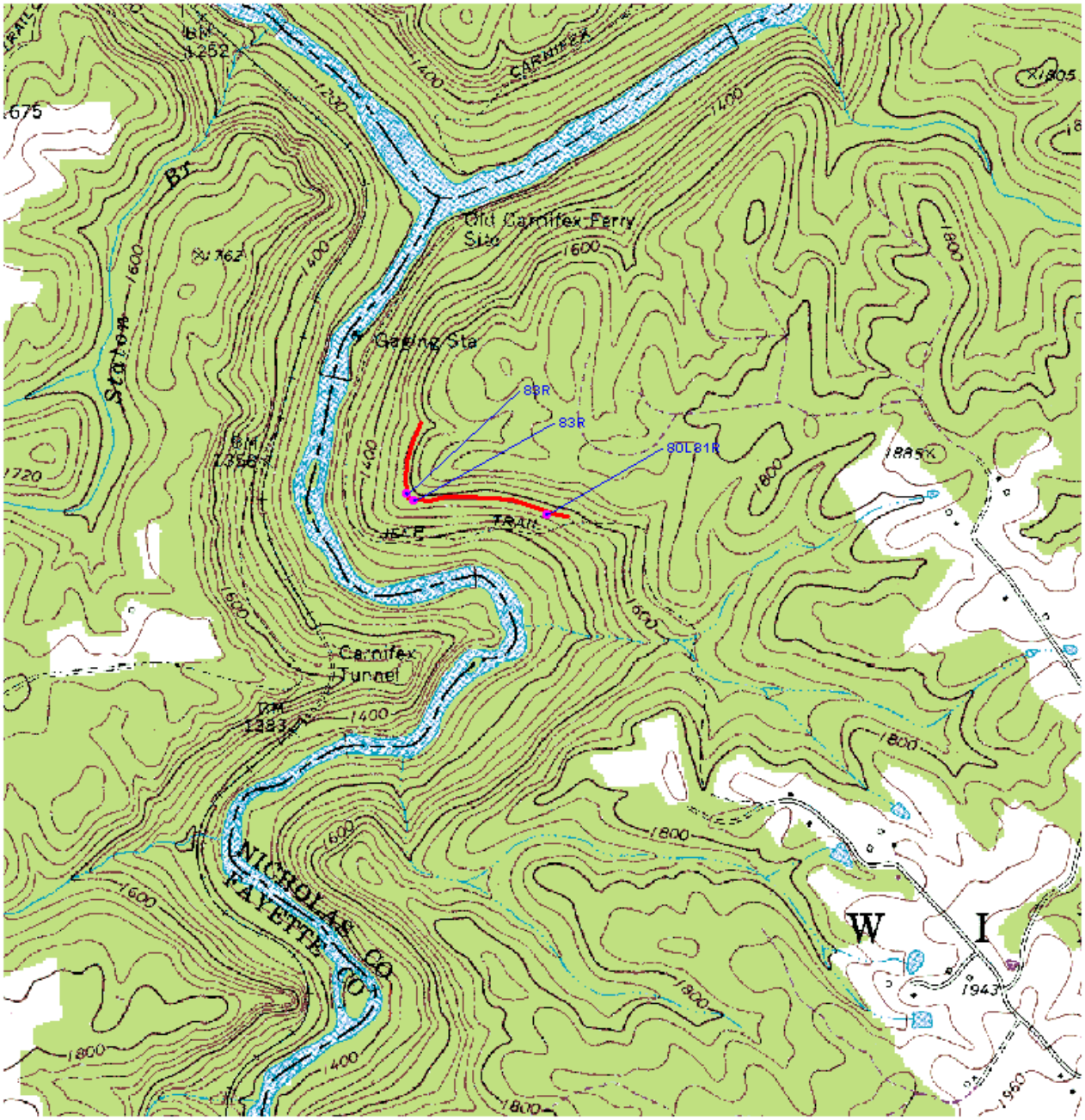
Individual Captures
Carnifex Ferry #1
Carnifex Ferry #2

200 0 200 400 Meters

N
W E
S

(Summersville Dam Quad -
Carnifex Ferry # 1, Carnifex Ferry # 2)

(Summer 1999)



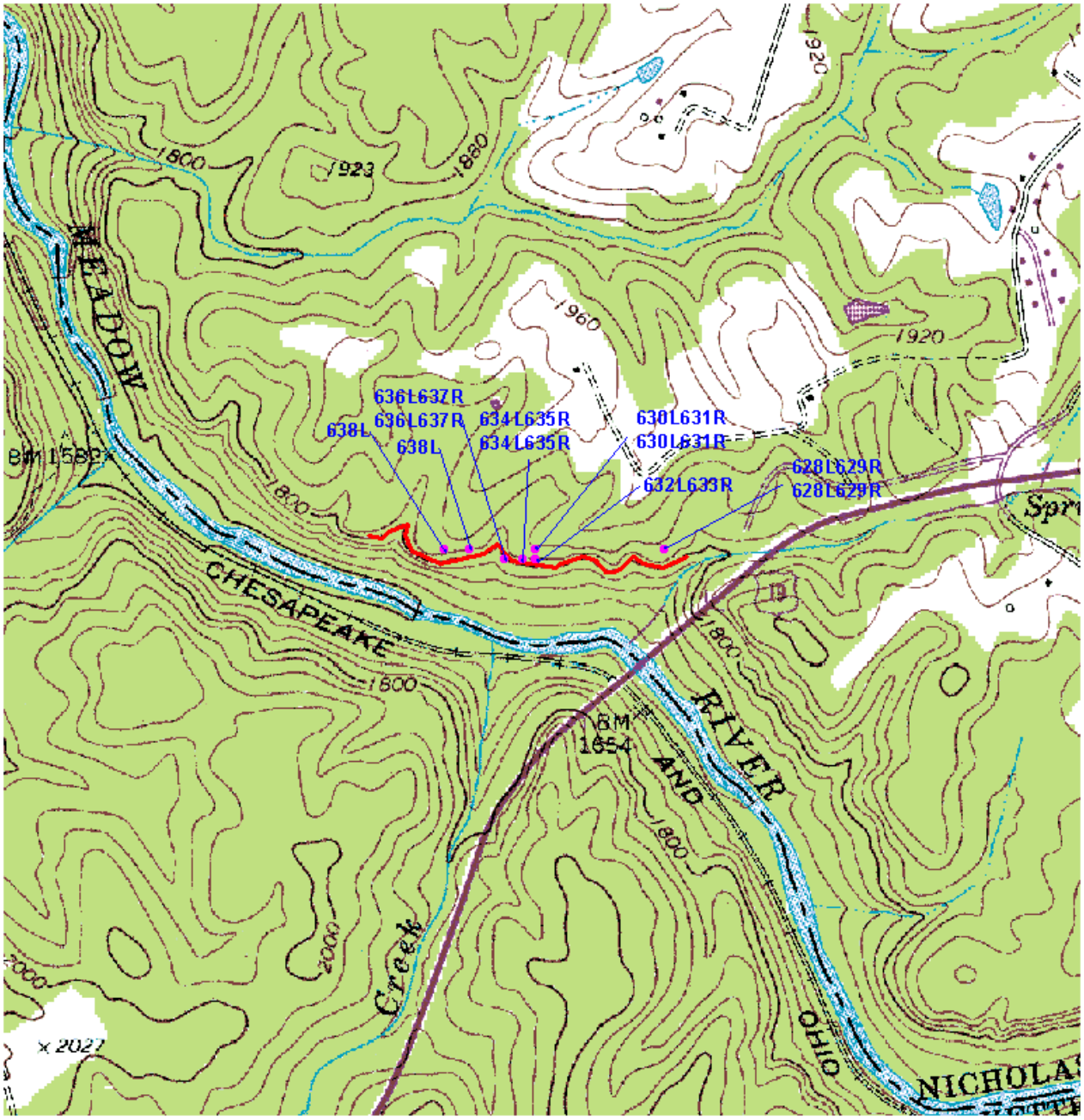
Individual Captures
Mt Lookout

200 0 200 400 Meters

N
W E
S

(Summersville Dam Quad - Mt. Lookout)

(Summer 1999)



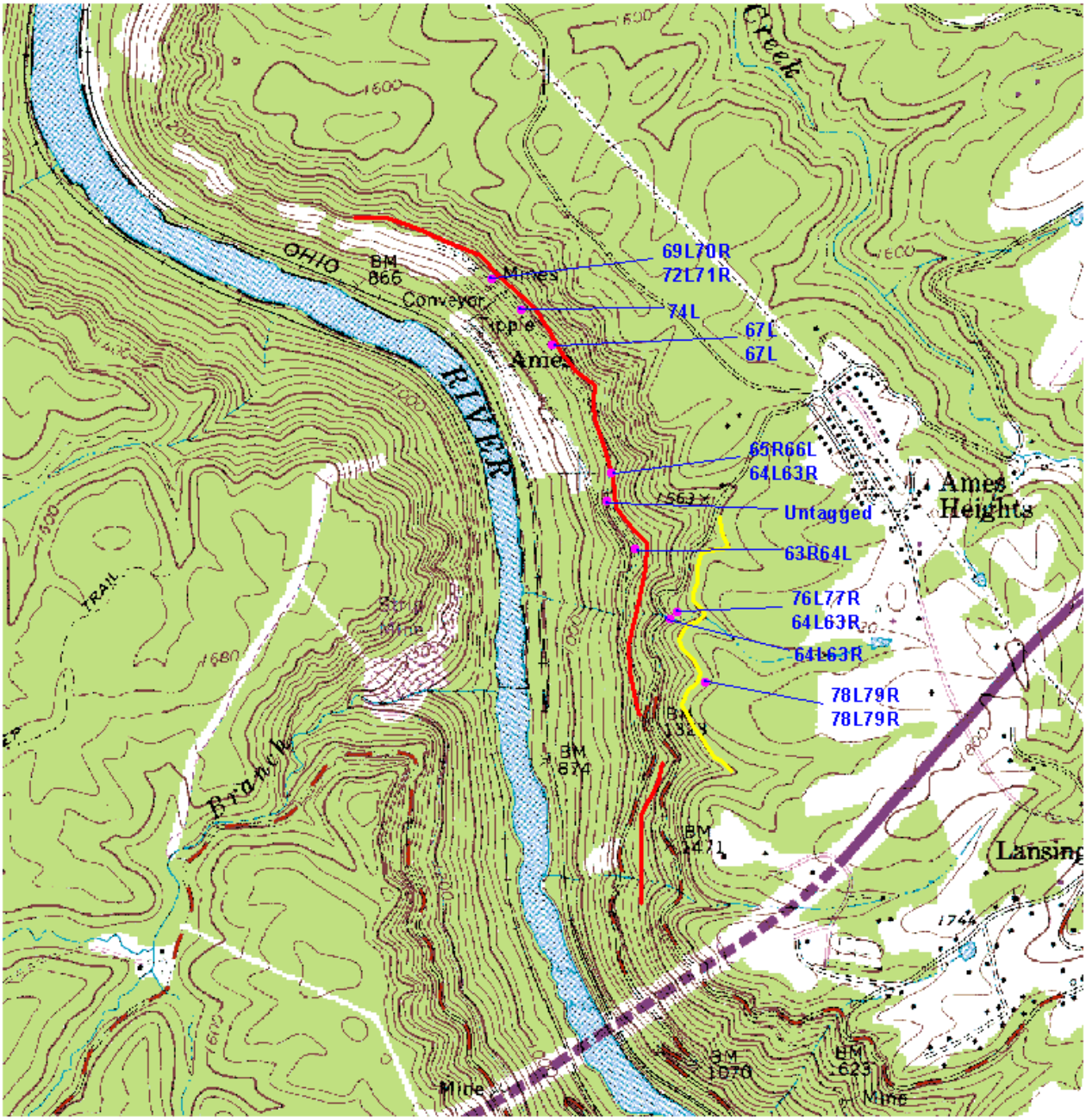
Individual Captures
Underwood Road

200 0 200 400 Meters

N
W E
S

(Summersville Dam Quad - Underwood Road)

(Summer 1999)



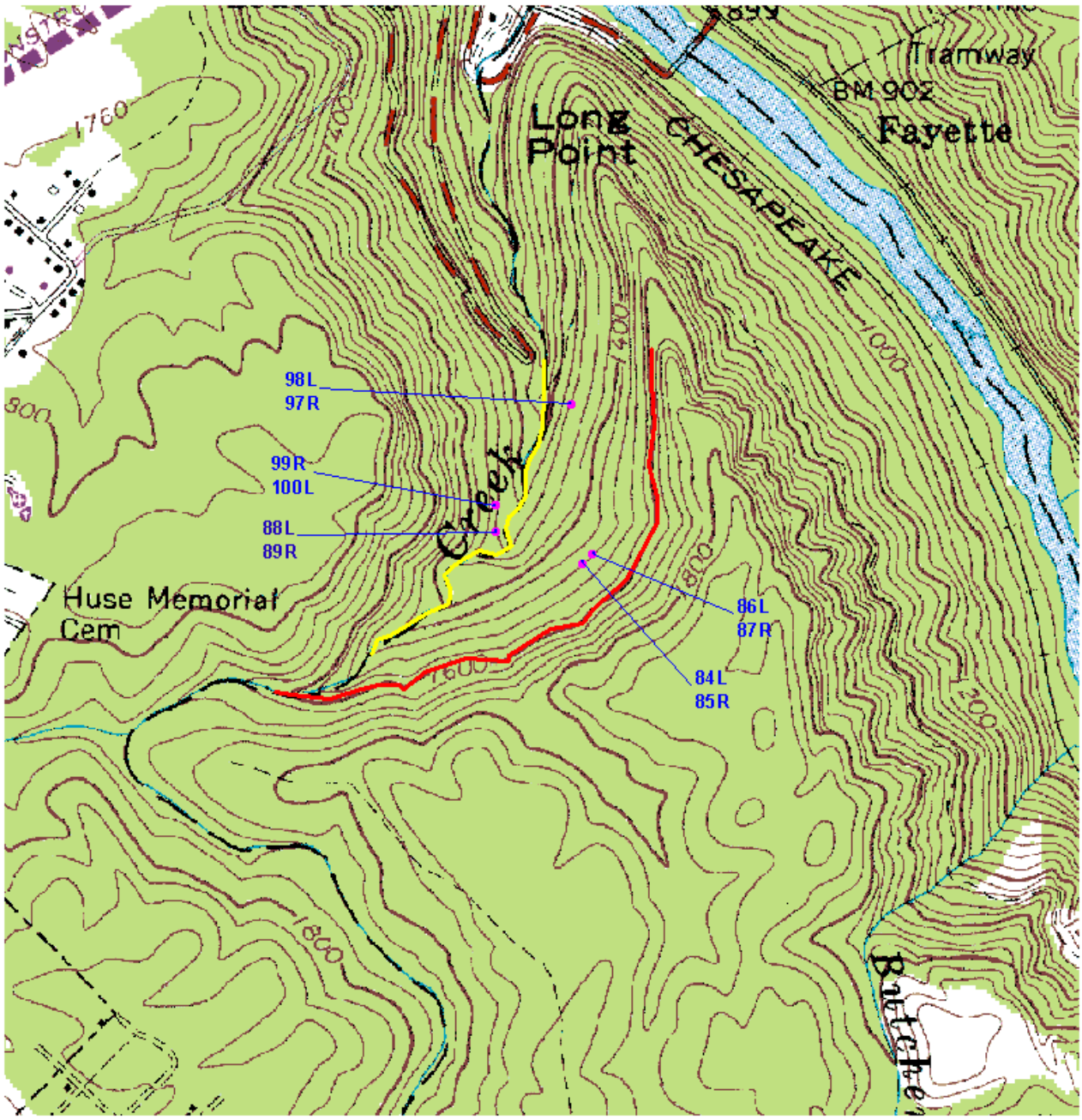
Individual Captures
Ames Mines
Ames Cliff

200 0 200 400 Meters

N
W E
S

(Fayetteville Quad - Ames Mines, Ames Cliff)

(Summer 1999)



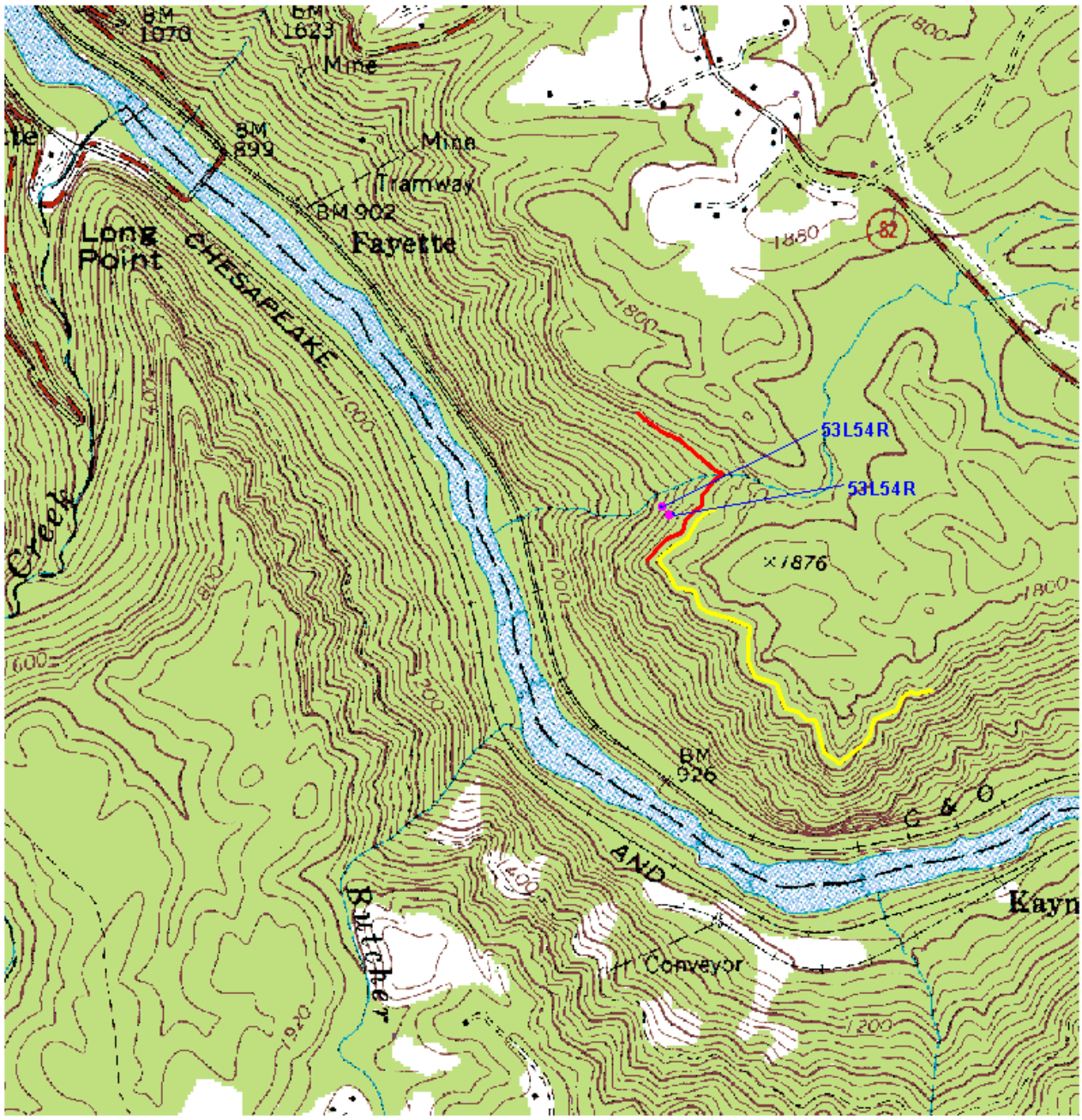
Individual Captures
Wolf Creek #1
Wolf Creek #2

100 0 100 200 Meters

N
W E
S

(Summer 1999)

(Fayetteville Quad -
Wolf Creek, Wolf Creek # 2)



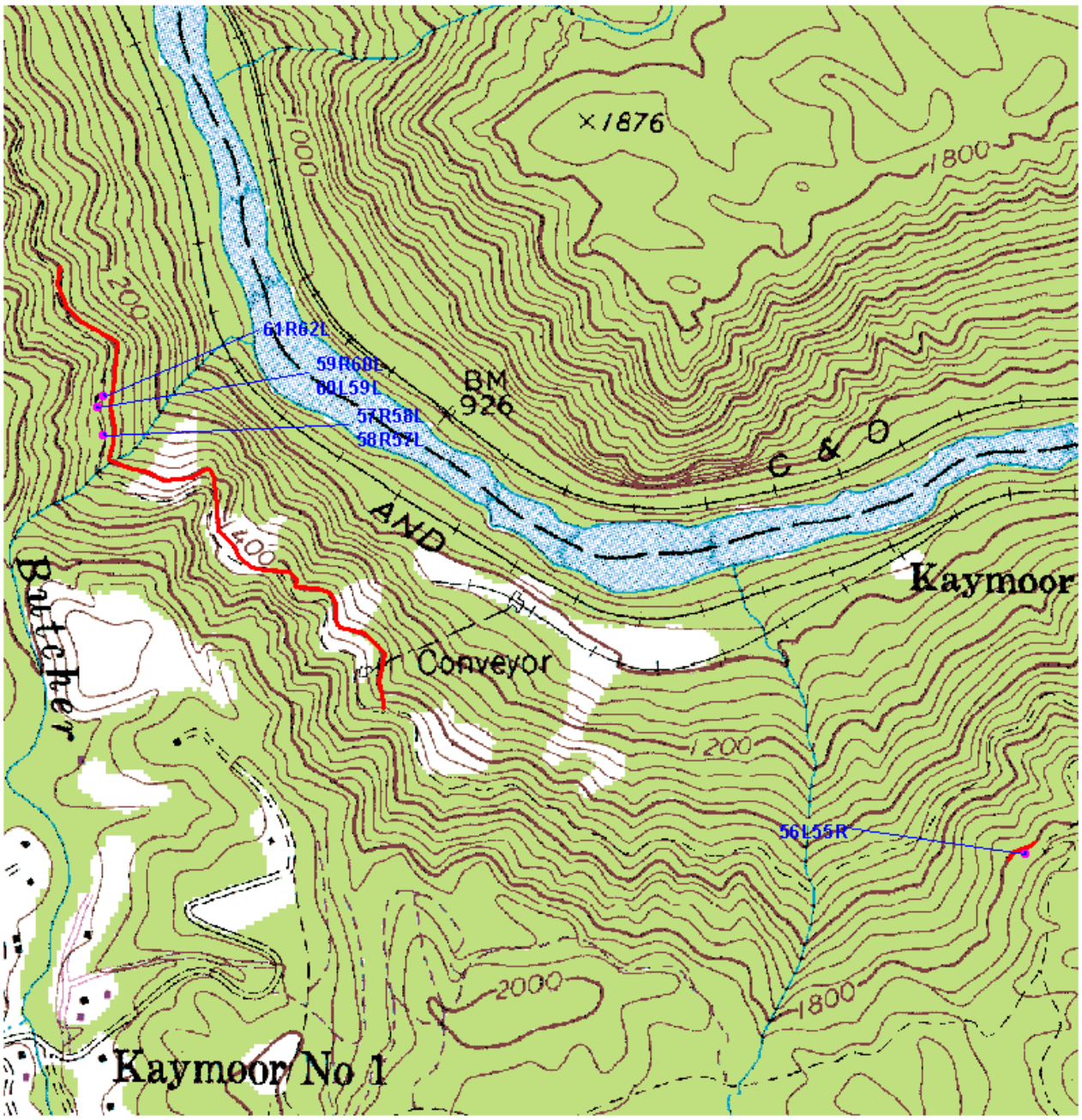
Individual Captures
Endless Wall #1
Endless Wall #2

200 0 200 400 Meters

N
W E
S

(Fayetteville Quad -
Endless Wall # 1, Endless Wall # 2)

(Summer 1999)



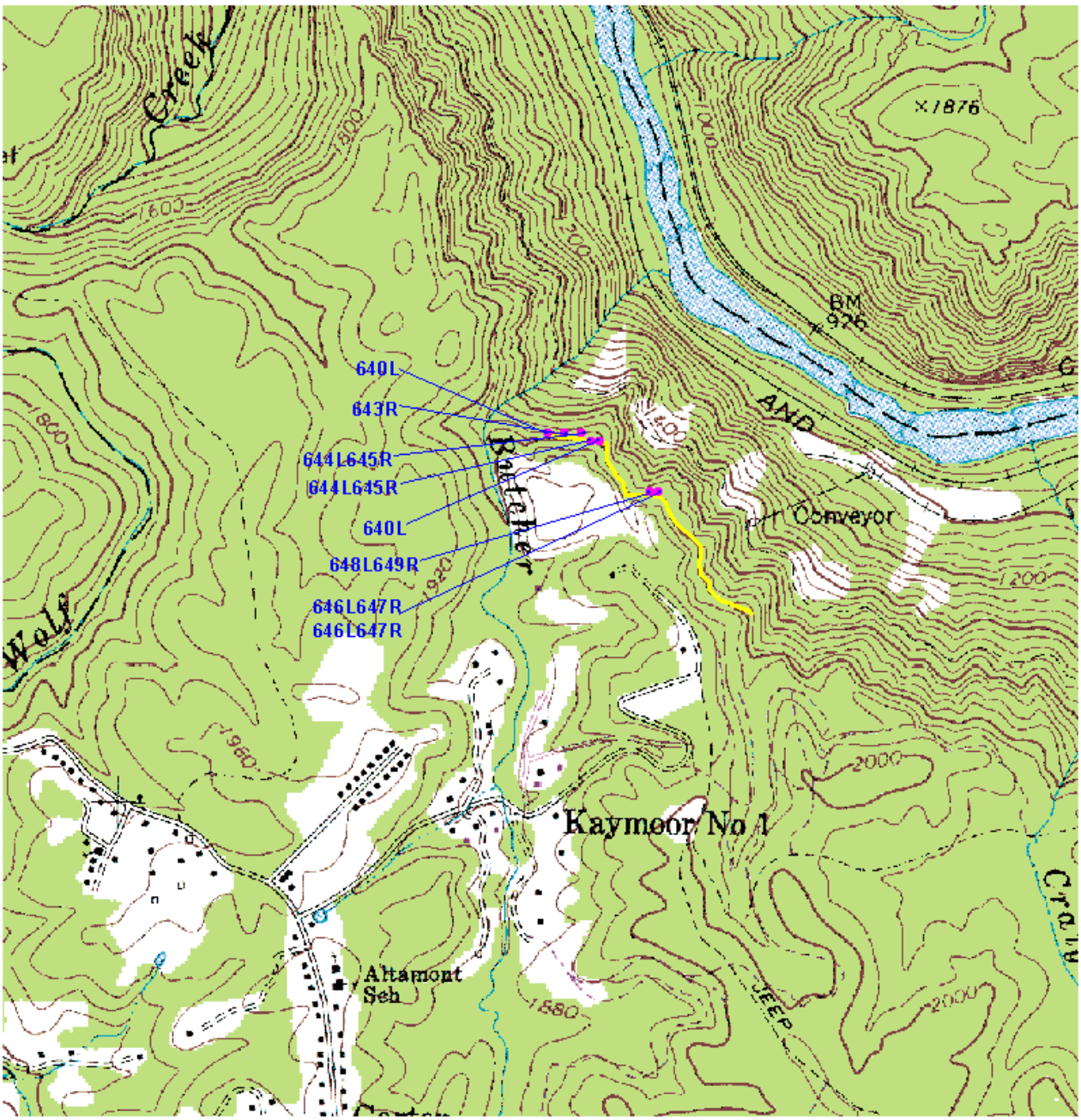
Individual Captures
Kaymoor Mines

100 0 100 200 Meters

N
W E
S

(Summer 1999)

(Fayetteville Mine - Kaymoor Mine)



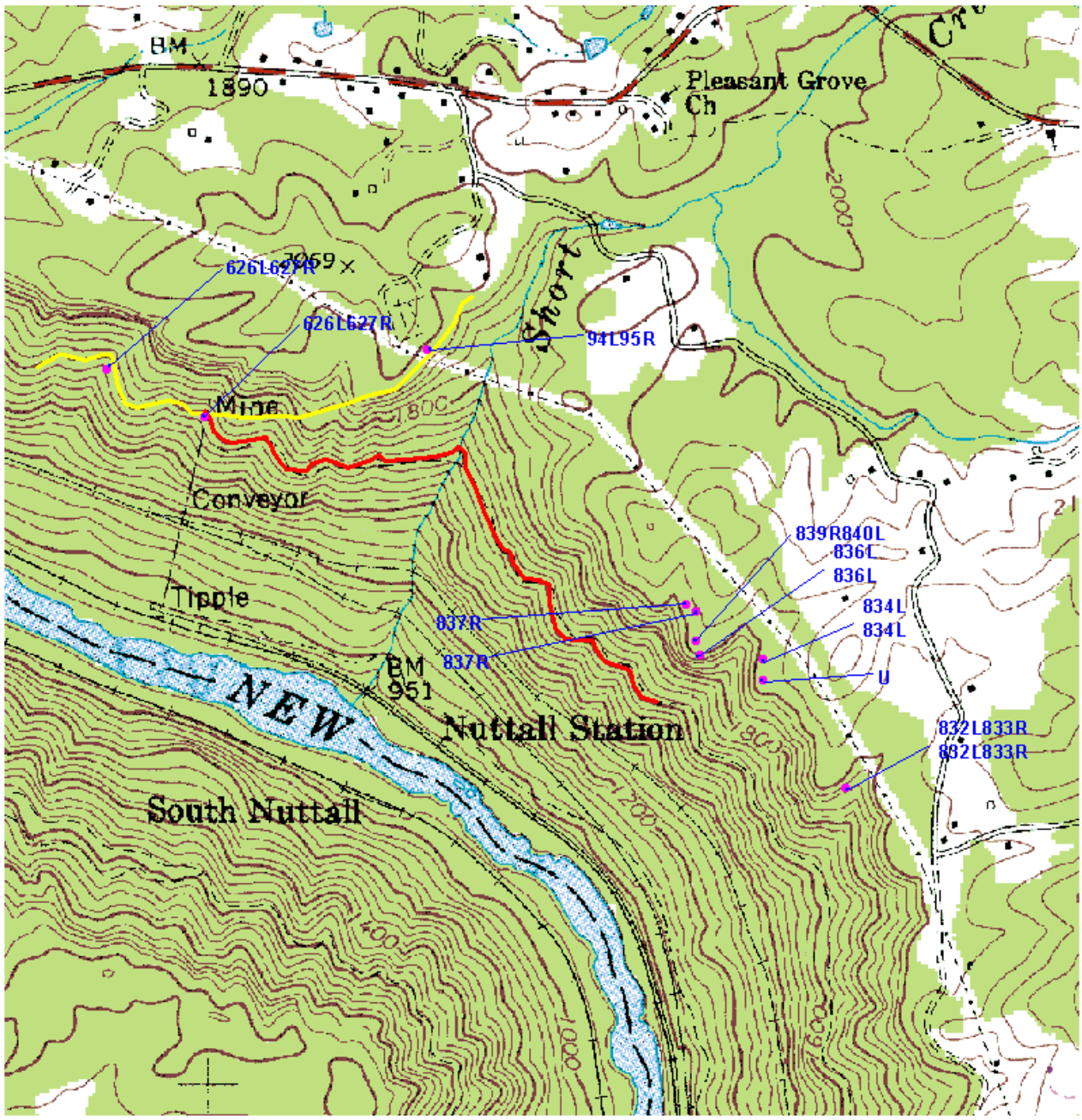
Individual Captures
Butcher's Branch

200 0 200 400 Meters

N
W E
S

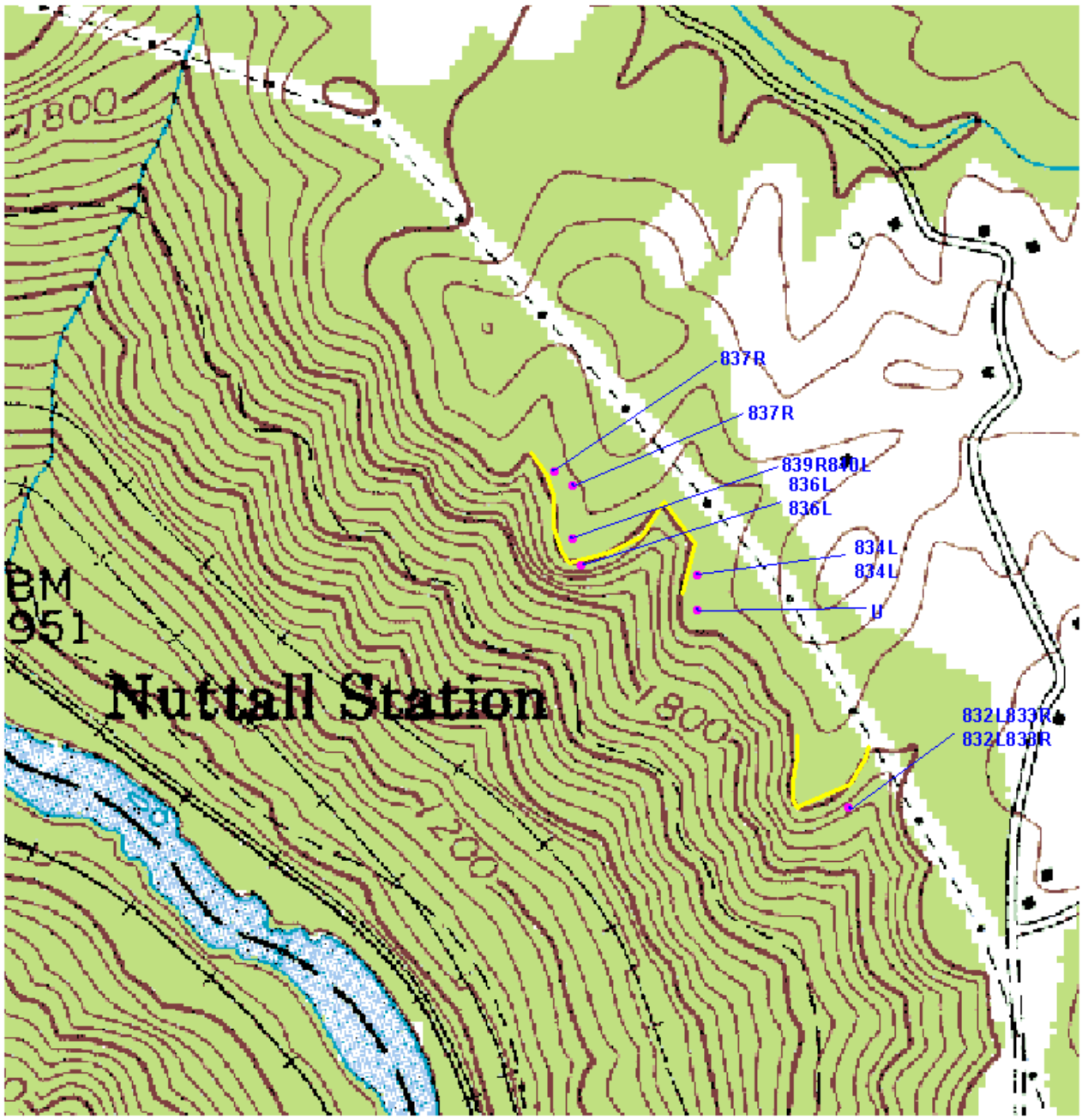
(Summer 1999)

(Fayetteville Quad) - Butcher's Branch



(Fayetteville Quad -
Nuttallberg Mines, Nuttall Cliff)

(Summer 1999)



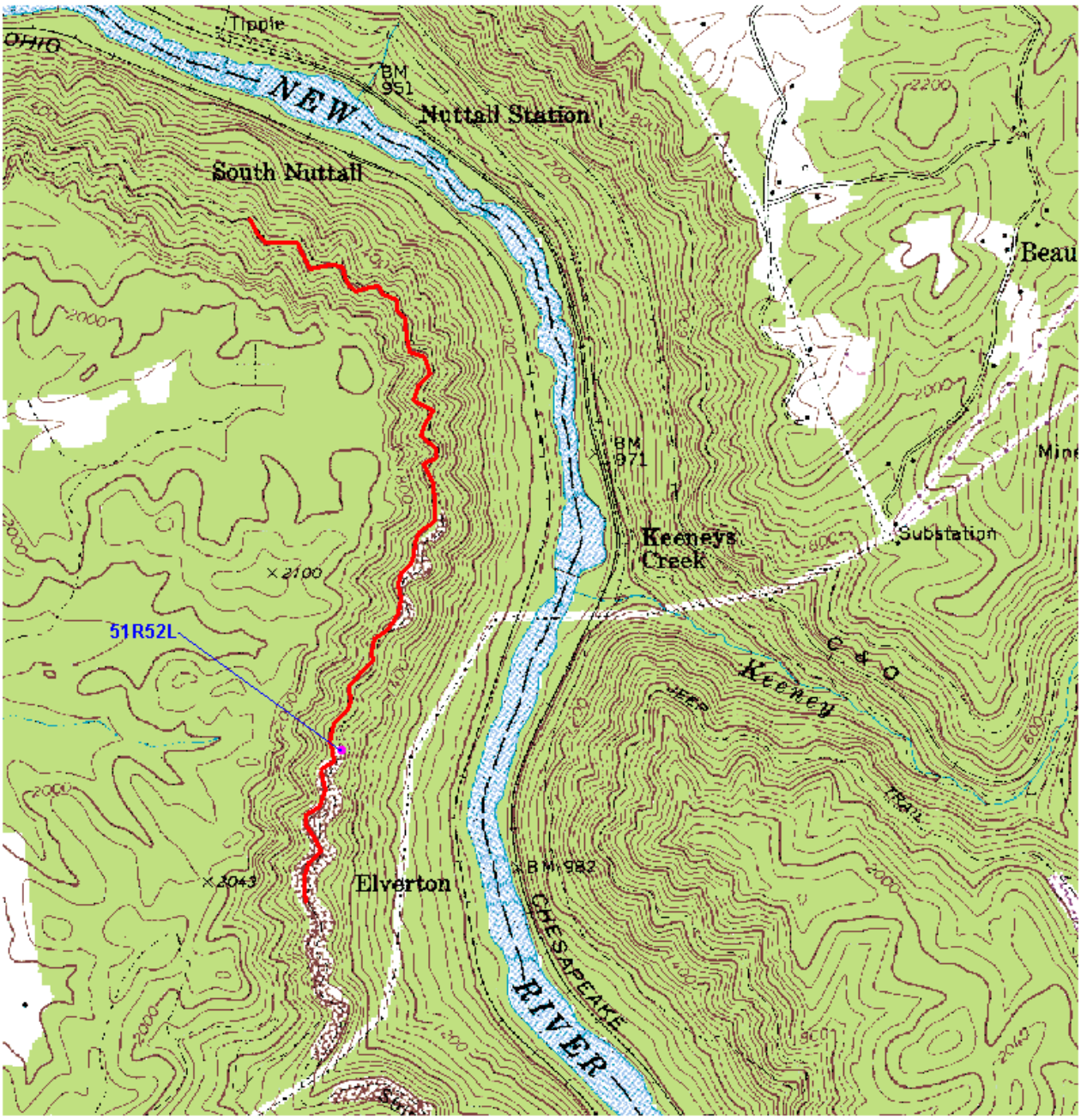
Individual Captures
Beauty Mt.

80 0 80 160 Meters

N
W E
S

(Summer 1999)

(Fayetteville Quad - Beauty Mountain)



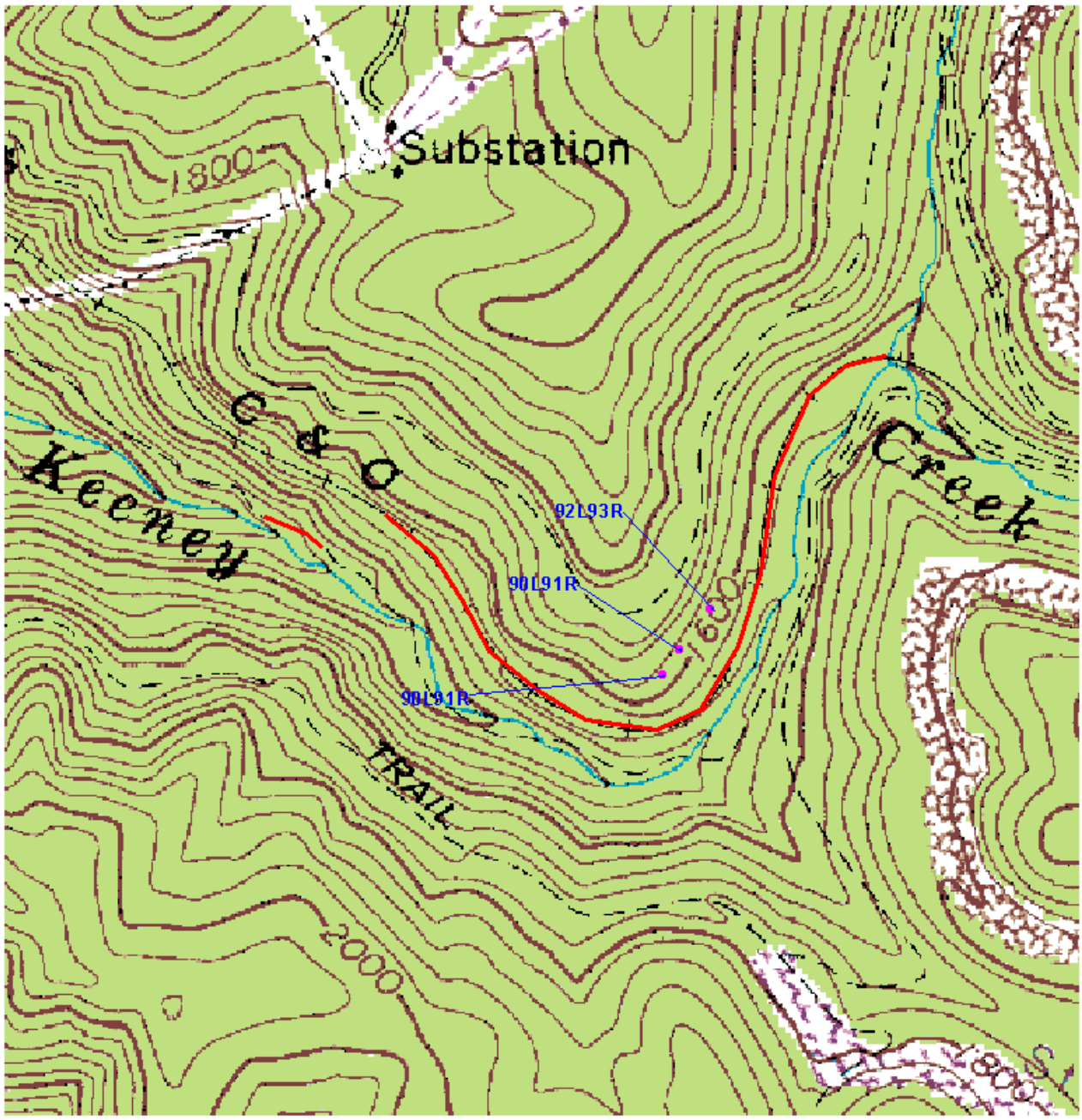
Individual Captures
Elverton Mines

200 0 200 400 Meters

N
W E
S

(Summer 1999)

(Fayetteville Quad - Elverton Mines)



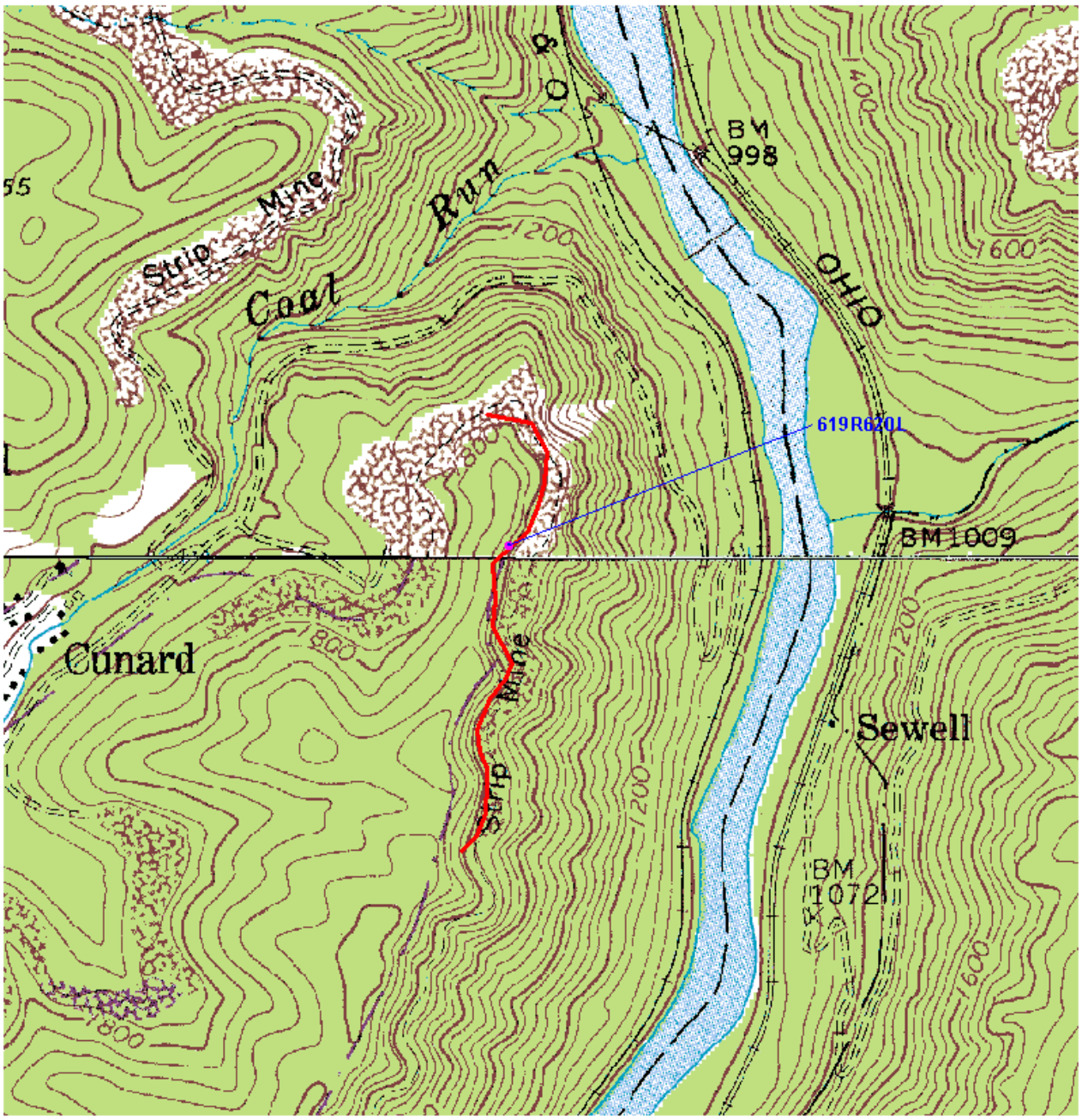
Individual Captures
Keeney's Creek

90 0 90 180 Meters

N
W E
S

(Summer 1999)

(Fayetteville Quad - Keeney's Creek)



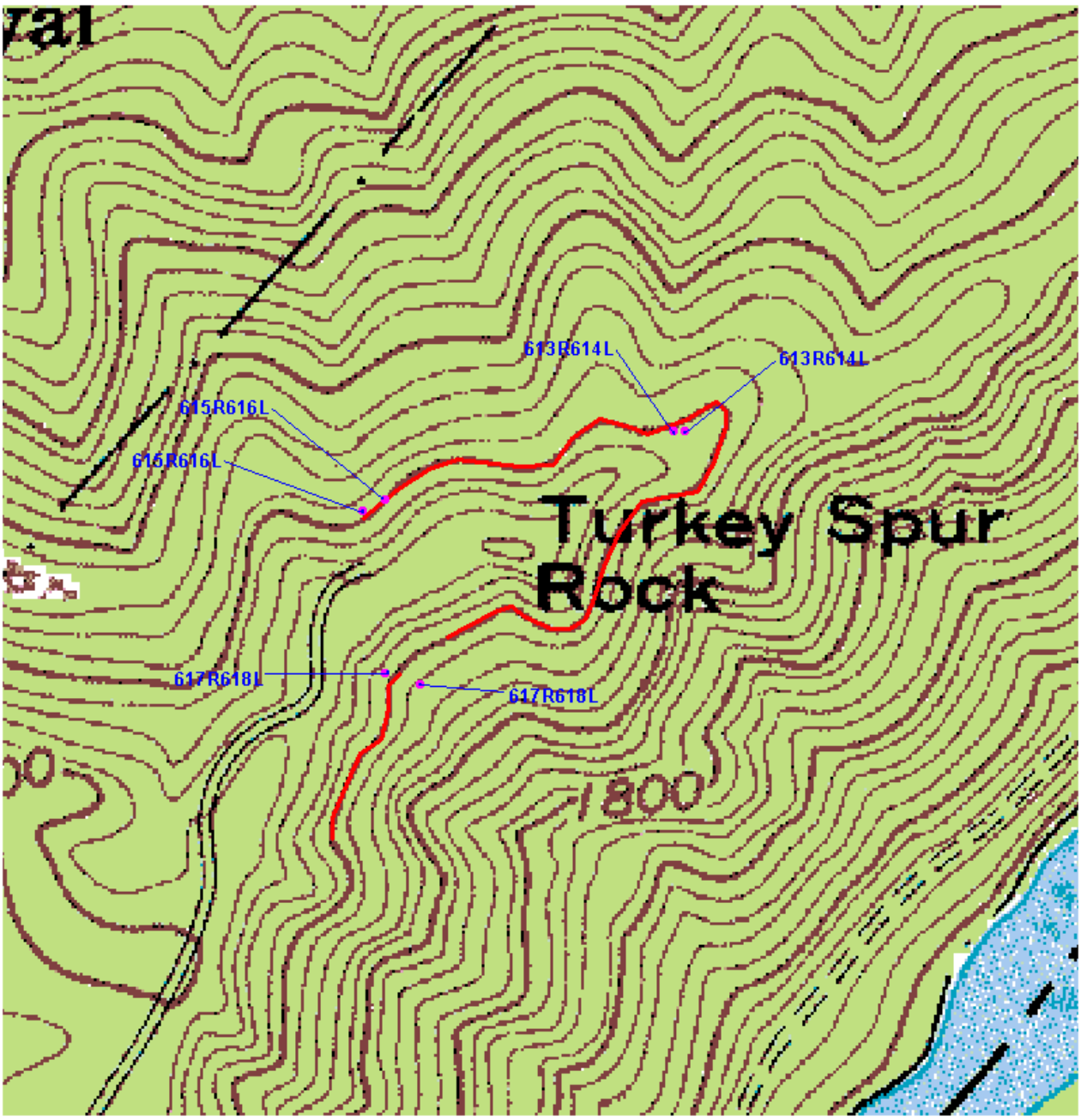
Individual Captures
Cunard South

100 0 100 200 Meters

N
W E
S

(Fayetteville and Thurmond Quads - Cunard South)

(Summer 1999)



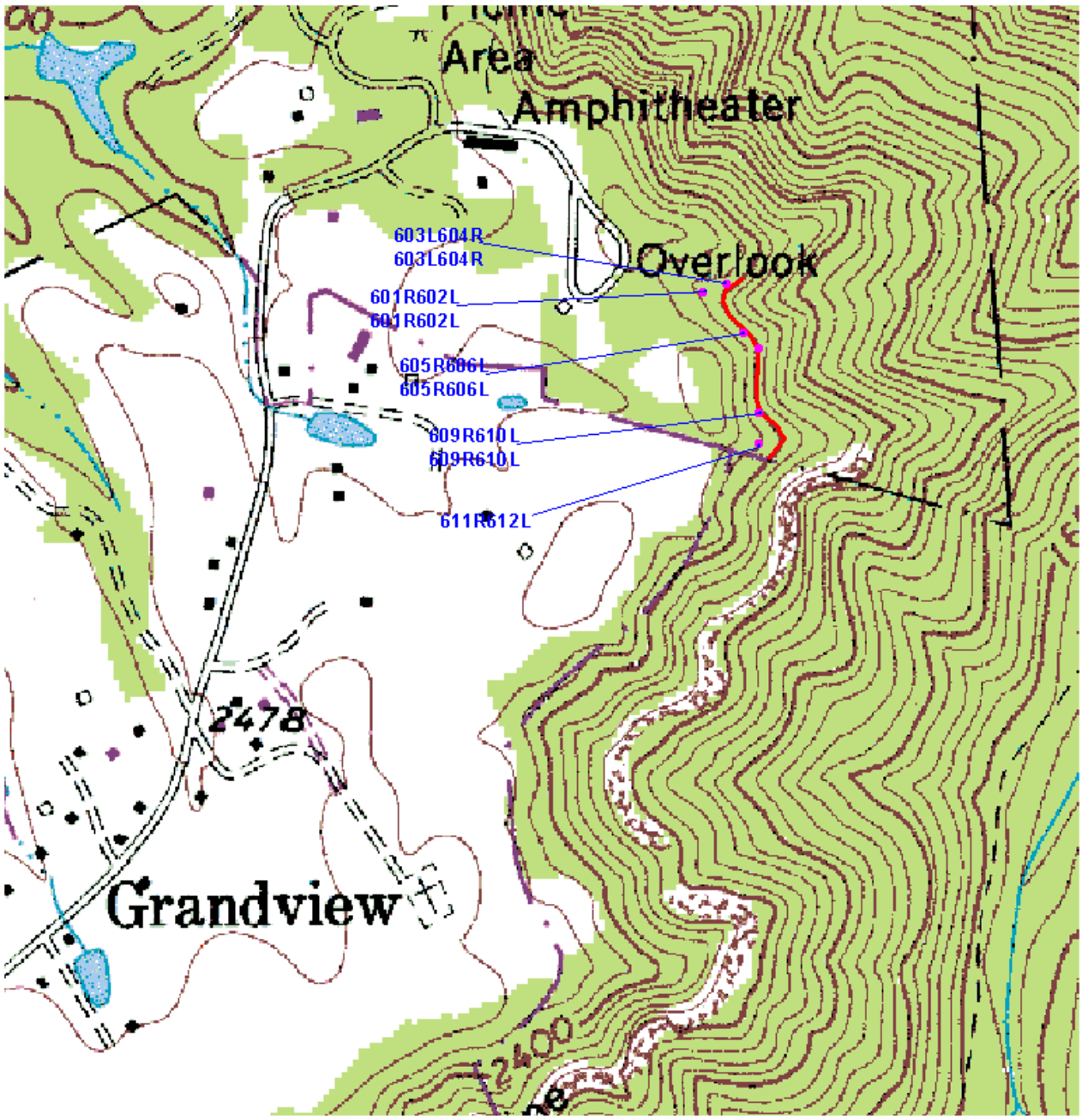
Individual Captures
Turkey Spur

60 0 60 120 Meters

N
W E
S

(Summer 1999)

(Prince Quad - Turkey Spur)



Individual Captures
Tunnel Trail

90 0 90 180 Meters

N
W E
S

(Summer 1999)

(Prince Quad - Tunnel Trail)

Appendix 2. Blank data sheets, detailed methods, and coding sheets for physical and vegetative characteristics include the following and appear in the order listed.

– woodrat trapping data sheet
– woodrat vegetation sampling form
– woodrat vegetation data collection protocol
– woodrat colony site characterizations
– classification codes for rocky habitats
– Anderson level III land-cover codes
– classification codes for habitat disturbance

WOODRAT TRAPPING DATA SHEET

DATE(S)_____ OBSERVER(S)_____

SITE _____ TEMP _____ MOON _____ % CLOUD COVER _____ PRECIP (Y/N) _____

NO. TRAPS _____ # NIGHTS OPEN _____ # CLOSED / SPRUNG _____

Date	Ear Tag No.	Wt (g)	Age	Sex	Repr. Cond	Gland	New or Recap	Comments	UTME/ UTMN

AGE
Juvenile (J): <175 grms, grey pelage
Subadult (S): 176-225 grms, slightly buffy
Adult (A): >225 grms, white ventor

REPRODUCTIVE CONDITION
Male: scrotal (S), non scrotal (NS)
Female: pregnant (P), lactating (L), post-repro (PR)

MID-VENTRAL GLAND 0 = not visible 1 = narow, covered with fur 2 = wide, bare skin, oily

WOODRAT VEGETATION SAMPLING FORM DATE _____ SITE _____

PLOT _____ OBSERVERS _____

UTMS OF CENTER POINT _____

TREES AND SNAGS (11.3m RADIUS CIRCLE)

SPECIES	**B** (8-15 cm)	**C** (15-30 cm)	**D** (30-45 cm)	**E** (> 45 cm)

SHRUBS, SAPLINGS, AND POLES (belt transects)

SPECIES	SHRUBS (< 3 cm AND < HEAD HIGH)	SAPLINGS (< 3 cm AND OVER HEAD)	POLES 3-8 cm

GROUND COVER		**SITE CHARACTERISTICS**
% forbes	% woody debris	aspect
% grass	% rock	% slope
% fern	% bare ground	
% leaf litter	% water	
% shrub cover		
% greenbrier	% blackberry	% canopy cover

WOODRAT VEGETATION DATA COLLECTION PROTOCOL

Data are collected within an 11.3 m radius (0.04 ha) plot

Total Plot Counts

1) Establish the plot center and pull the 11.3 m ropes in the four cardinal directions.

2) Count all trees > 8 cm within the entire plot and tally the number of each species in each size class on the top section of the data sheet [columns B-E].

- snags are recorded as SNAG and assigned to a size class (no species recorded).

Belt Transects

Walk along each line with the rope centered between your feet and holding a meter stick horizontal, perpendicular to the line, and 4.5 feet from the ground. Tally shrubs, saplings, and poles that contact the meter stick or hang above the meter stick on the middle section of the data sheet. (any vegetation < 4.5 feet tall is included in ground cover measurements.)

- shrubs are defined as any woody species less than 2 m high (head high is the typical measure). Mountain Laurel, Rhododendron, and Greenbrier are always recorded as shrubs no matter how high.
- saplings are defined as woody species > 2 m high and less than 3 cm DBH
- poles are woody species 3-8 cm DBH

Ground and Canopy Cover, Aspect, and Slope

1) Five stations are marked along each rope, for a total of 20 stations (the center is not a station). While walking each line, stop at each station and site through the ocular tube for canopy and ground cover.

- First, hold the tube perpendicular to the ground just above waist level. With your eyes closed, hold your head over the tube, open your eyes and record the type of ground cover in the crosshairs.
- Next, hold the tube directly over your head with your eyes closed, open your eyes and record whether or not the crosshair fell on any canopy cover over the height of the tube (the measurement will be a hit or miss for canopy cover).

2) Aspect is an azimuth (0-359) in the direction the slope is facing (measure with compass).

3) Percent slope is the change in elevation over the change in horizontal distance (rise over the run) measured by clinometer or compass.

WOODRAT COLONY SITE CHARACTERIZATIONS

SITE_____ DATE _____

OBSERVER(S)_____

DIRECTIONS TO SITE _____

_____

_____

WOODRAT SIGN PRESENT (indicate type and age): _____

_____

OCCUPIED NOT OCCUPIED (circle one)

<table>
<tr><td>ELEVATION</td><td>ROCK TYPE
(circle)</td><td>CANOPY
COVER</td><td>HABITAT CLASSIFICATION</td></tr>
<tr><td>SLOPE:</td><td rowspan="6">1. Talus/boulder

2. Float block

3. Cave

4. Mine
(open portal)
5. Cliff/rubble

6. Mine
(closed portal)</td><td rowspan="6">_____full

_____half to full

_____less than half</td><td>Rocky
Habitat Code:</td></tr>
<tr><td>ASPECT:</td><td>Land
Cover Code:</td></tr>
<tr><td>LENGTH:</td><td>Disturbance Code:
(within 500 m)</td></tr>
<tr><td>WIDTH:</td><td>Forest Type:
(major plants)</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

GENERAL COMMENTS:

Classification Codes for Rocky Habitats

[From: Pennsylvania Game Commission. 1996. Allegheny Woodrat Site Survey Code Manual. Bureau of Wildlife Management, Harrisburg, Pennsylvania. 11pp.]

Enter as a three-digit code from the following matrix:

HABITAT TYPE	QUALITY OF HABITAT	SIZE OF ROCK
1. Talus	11 bare rock, deep interstices	111 blocks less than 1 meter 112 blocks 1-3 meters 113 blocks 3-5 meters
	12 bare rock, shallow interstices	121 blocks less than 1 meter 122 blocks 1-3 meters 123 blocks 3-5 meters
	13 rock covered by organic material including humus, leaves, moss, with deep interstices	131 blocks less than 1 meter 132 blocks 1-3 meters 133 blocks 3-5 meters
	14 rock covered by organic material including humus, leaves, moss with shallow interstices	141 blocks less than 1 meter 142 blocks 1-3 meters 143 blocks 3-5 meters
2. rock city, large float blocks	21 numerous overhangs, crevices, and “caves”	211 blocks 5-10 meters 212 blocks 10 meters
	22 few or no overhangs, crevices and “caves”	221 blocks 5-10 meters 222 blocks 10 meters
3. cliffs, rock outcrops	31 numerous overhangs, crevices and “caves”	311 less than 3 meters high 312 3+ meters high
	32 few or no overhangs, crevices and “caves”	321 less than 3 meters high 322 3+ meters high
4. cave or mine passage	41 rarely visited, may be gated	411 entrance 0-2 meters 412 entrance 2+ meters
	42 occasionally visited	421 entrance 0-2 meters 422 entrance 2+ meters
	43 active, heavily visited, or commercialized	431 entrance 0-2 meters 432 entrance 2+ meters
5. quarry or mine pit	51 highwall with numerous crevices, boulders, etc.	511 less than 3 meters high 512 3+ meters high
	52 highwall with few or no crevices, boulders, ect.	521 less than 3 meters high 522 3+ meters high
6. other man-made rocky habitat, such as stone wall, railroad and road cuts, ruins, buildings, etc.	61 few or no suitable crevices, overhangs, or other interstices	611 less than 3 meters high 612 3+ meters high
	62 numerous suitable crevices, overhangs, or other interstices	621 less than 3 meters high 622 3+ meters high

Anderson Level III Land-Cover Codes

[From: Pennsylvania Game Commission. 1996. Allegheny Woodrat Site Survey Code Manual. Bureau of Wildlife Management, Harrisburg, Pennsylvania. 11pp.]

1. urban or built-up land	11 residential	
	12 commercial and services	
	13 industrial	
	14 transportation, communications, and utilities	
	15 industrial and commercial complex	
	16 mixed urban or built-up land	
	17 other urban or built-up land	
2. agricultural land	21 cropland and pastures	211 cropland
		212 pastureland
		213 hayland
	22 orchards, groves, vineyards, nurseries and ornamental horticultural areas	
	23 confined feeding operations	
	24 other agricultural land	
3. rangeland	31 herbaceous rangeland not grazed, at least 2/3 herbs, grass, and grasslike vegetation	311 herbaceous rangeland: mowed areas such as recreation fields
		312 herbaceous rangeland: early succession old field
	32 shrub and brush rangeland at least 2/3 of area grown up in shrubs	321 shrub and brush rangeland: shrub layer moderate dense – lateral visibility somewhat restricted
		322 shrub and brush rangeland: area grazed and/or shrub layer vegetation thin and scattered, lateral visibility relatively good
	33 mixed rangeland more than 1/3 intermixture of either shrub and brush rangeland or herbaceous rangeland	331 mixed rangeland: shrub and herbaceous layer vegetation moderate to dense
		332 mixed rangeland: area grazed and/or herbaceous and shrub layer vegetation thin
4. forest land	41 deciduous forest	411 sapling stage: shrub land layer moderate to dense
		412 sapling stage: grazed and/or shrub layer sparse
		413 pole stage: shrub layer moderate to dense
		414 pole stage: grazed and/or shrub layer sparse
		415 mature stage: shrub layer moderate to dense
		416 mature stage: grazed and/or shrub layer sparse
	42 evergreen tree land	421 sapling stage: shrub land layer moderate to dense
		422 sapling stage: grazed and/or shrub layer sparse
		423 pole stage: shrub layer moderate to dense
		424 pole stage: grazed and/or shrub layer sparse
		425 mature stage: shrub layer moderate to dense
		426 mature stage: grazed and/or shrub layer sparse

	43 mixed forest land	431 sapling stage: shrub land layer moderate to dense 432 sapling stage: grazed and/or shrub layer sparse 433 pole stage: shrub layer moderate to dense 434 pole stage: grazed and/or shrub layer sparse 435 mature stage: shrub layer moderate to dense 436 mature stage: grazed and/or shrub layer sparse
7. barren land	70 marine 71 dry salt flats 72 beaches 73 sandy areas other than beaches 74 bare exposed rock 75 strip mines, quarries, and grade pits 76 transitional areas 77 mixed barren land	700 marine 710 dry salt flats 720 beaches 730 sandy areas other than beaches 740 bare exposed rock 750 strip mines, quarries, and grade pits 760 transitional areas 770 mixed barren land

Classification Codes for Habitat Disturbance

[From: Pennsylvania Game Commission. 1996. Allegheny Woodrat Site Survey Code Manual. Bureau of Wildlife Management, Harrisburg, Pennsylvania. 11pp.]

Use the category that best defines the site:

PROXIMITY OF DISTURBANCE

1. Disturbance on site
2. Disturbance within 100 meters of site
3. Disturbance 100-500 meters of site
4. Disturbance 500-1000 meters of site
5. Disturbance 1-2 kilometers from site
6. Disturbance 2-5 kilometers from site
7. No significant disturbance

TYPE OF DISTURBANCE

A. Dumping
B. Party spot
C. Buildings
D. Agriculture
E. Utility rights-of-way
F. Railroad rights of way
G. Improved roads
H. Unimproved roads
I. Recreation area
J. Mining
K. Fire
L. Clearcut
M. Insect defoliation
N. No disturbance

Example 1: Pastureland approximately 600 meters from suitable rocky habitat would be coded **4D**.

Example 2: A rock outcrop/cliff used for beer parties would be coded **1B**.

Example 3: Excellent rocky habitat surrounded by uninterrupted forest for 5 kilometers in every direction would be coded **7N**.